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SPECTRAL VARIABILITY OF QSOs IN THE OPTICAL BAND

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ABSTRACT. A new analysis of the variability of the spectral slope of PG QSOs has been performed, on the basis of recent literature data in the B and R photometric bands. Preliminary results confirm our previous findings concerning the increase of variability with the rest-frame observing frequency. We also find a correlation of the spectral slope with luminosity, consistent with temperature changes of an emitting black body.

1. Introduction

Although variability plays a key role in constraining the models of the central engine of QSOs, little is known about the physical origin of luminosity variations. The most diverse variability mechanisms have been proposed in the past, including supernovae explosions (Aretxaga et al. 1997), instabilities in the accretion disk (Kawaguchi et al. 1998), and gravitational lensing due to intervening matter (Hawkins 1993). So far, most of the information about the characteristics of variability derives from the statistical analysis of single band light curves of magnitude limited QSO samples. The correlation of variability with either intrinsic luminosity (v-L) or redshift (v-z) is affected by the strong correlation between luminosity and redshift (L-z), present in these samples. The results of these analyses also depend on the specific variability index adopted, as shown by Giallongo et al. (1991, GTV), who found a positive v-z correlation through a variability index based on the rest-frame structure function, later confirmed by Cristiani et al. (1996). The increase of variability with the rest-frame observing frequency found by Di Clemente et al. (1996), supports the suggestion of GTV that QSOs at high redshift appear more variable, on average, since they are observed in a higher rest frame frequency. The dependence of variability on frequency is associated with the hardening of the spectral energy distribution (SED) during the bright phases (Cutri et al. 1985, Kinney et al. 1991, Edelson et al. 1990). Trèvese et al. (1999) have shown that a hardening of the SED in the bright phase occurs, on average, in the statistical, magnitude limited, sample of AGNs of the SA 57 (Trèvese et al. 1989, 1994, Bershady et al. 1998). They also found that the slope α and its variations associated with the luminosity changes, are consistent on average with temperature changes of a black body.

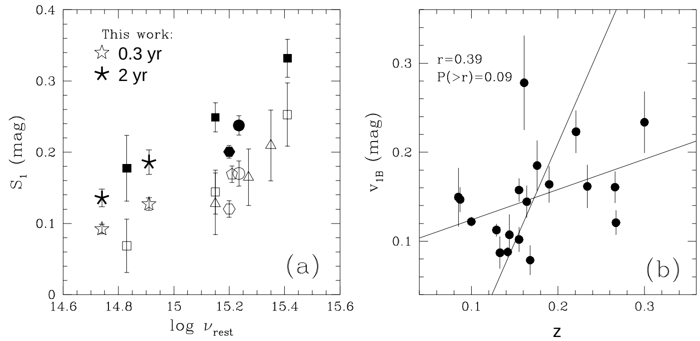

Fig. 1. (a) Variability vs. rest-frame frequency for various QSO samples, adapted from Di Clemente et al. 1996. New points are represented by stars. (b) Variability vs. redshift for the subsample with $-23.5 < M_B < -22.5$.

2. Analysis and results

In a recent paper, Giveon et al. (1999) provide the light curves of a subsample of PG quasars consisting of 42 nearby and bright QSOs ($z < 0.4$, $B < 16$ mag) which were monitored for 7 years in the Johnson Cousins B and R bands, with the 1 m telescope of the Wise Observatory, with a typical sampling interval of 39 days. We define the structure function as (see Di Clemente et al. 1996) $S = \sqrt{\pi/2\langle|m(t+\tau) - m(t)|\rangle^2 - \sigma_n^2}$, where $m(t)$ is either the B or the R magnitude, t is the rest-frame time, τ is the time lag between the the observations, σ_n is the relevant r.m.s. noise and the angular brackets indicate the average taken over all the pairs of observations separated by a time interval $\tau \pm \Delta\tau$. The value of $\Delta\tau$ is the result of a trade-off between time resolution and statistical uncertainty. In the following we define, for each QSO and for each band, two different variability indexes v_1 and v_2 defined as S, computed for $\tau = 0.3 \pm 0.09$ yr and for $\tau = 2 \pm 0.6$ yr respectively. The average values of v_{1B}, v_{1R}, v_{2B}, v_{2R} over the ensemble of 42 QSOs, versus the relevant average rest-frame frequency, are reported in Figure 1a, which is adapted from Di Clemente et al. (1996). The new points are consistent with the general trend and confirm the value of the slope $\partial S_1/\partial \log \nu_{rest} = \partial S_1/\partial \log(1+z) \simeq 0.25 - 0.3$ which accounts for the v-z correlation found by GTV. Although this correlation is not present for the whole sample (Giveon et al. 1999), due to the small redshift range ($z < 0.4$), the v-z correlation appears (see Fig. 1b), if we restrict to an absolute magnitude bin $-23.5 < M_B < -22.5$, to reduce the effect of the (positive) L-z and (negative) v-L correlations. The correlation coefficient $r_{v,z} = 0.39$ is only marginally significant ($P(> r) = 0.09$), since the number of QSOs in the selected magnitude bin is only 19. Therefore, the v-z correlation and its interpretation in terms of spectral variability are confirmed, despite the poor statistics and the narrow redshift range. For each QSO we computed the instantaneous spectral slope $\alpha(t) \equiv \log(f_{\nu_B}/f_{\nu_R})/\log(\nu_B/\nu_R)$, regarding as synchronous the observations within a time lag of 9 hours. In Figure 2 $\alpha(t)$ is shown for each QSO at each observing time as a function of the monochromatic luminosity L_ν at a fixed rest-frame frequency. The regression lines α vs. $\log L_\nu$ are also reported

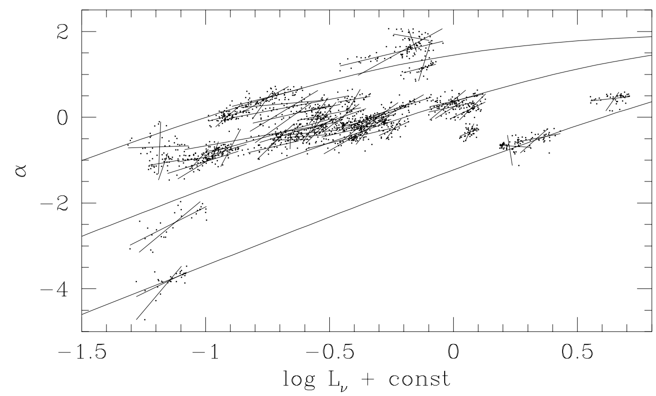

Fig. 2. Spectral slope α vs. monochromatic luminosity at each observing time. Regression lines α-L_ν are reported for each QSO. The three curves represent black bodies of different areas, with temperature as a free parameter.

for each QSO. With a few exceptions, a general trend of increasing α for increasing $\log L_\nu$ appears. Moreover, the average α of each QSO is also positively correlated with the average luminosity. This fact suggests that both the increase of α during luminosity variations and the average increase of α from faint to bright QSO have similar physical origins, like e.g. the increase of temperature of the emitting gas. For comparison in Figure 2 are reported the $\alpha(t)$ versus $\log L_\nu(t)$ lines computed for three emitting black bodies of different area. This admittedly oversimplified model accounts qualitatively for both the intra-QSO and the inter-QSO $\alpha(t) - \log L_\nu(t)$ correlation. Future comparison with different emission models will indicate their consistency or inconsistency with SED variability data.

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